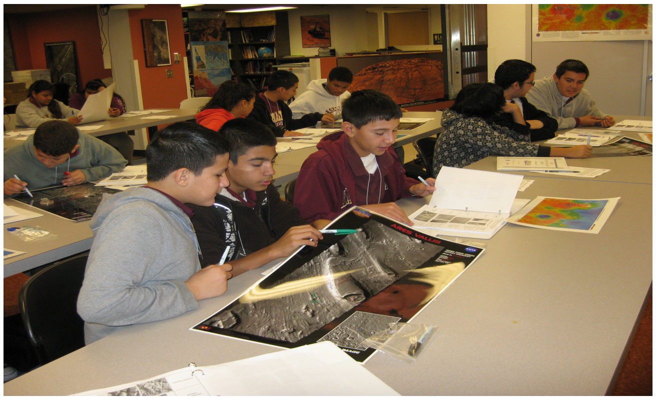
Mars Image Analysis

High School NGSS, Common Core, and 21st Century Skills Alignment Document



WHAT STUDENTS DO: Establish geologic sequences in a Mars image.

Students step into the shoes of real planetary scientists. Using large-format images of Mars, provided by Mars Education at Arizona State University, students reach conclusions about the geology of Mars. Students are tasked with identifying features on the surface of Mars, determining the surface history of the area, calculating the size of features, and developing research questions.

NGSS CORE & COMPONENT QUESTIONS

WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth's Place in the Universe

How do people reconstruct and date events in Earth's planetary history?

NRC ESS1.C: The History of the Planet Earth

How do Earth's major systems interact?

NRC ESS2.A: Earth Materials and Systems

INSTRUCTIONAL OBJECTIVES

Students will be able

IO1: to reconstruct geologic events using empirical evidence

IO2: to use an argument to establish a research topic through collaborative debate and decision making

1.0 About This Activity

Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. The 5E stages can be cyclical and iterative.

2.0 Instructional Objectives, Learning Outcomes, & Standards

Instructional objectives and learning outcomes are aligned with

- National Research Council's, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*
- Achieve Inc.'s, *Next Generation Science Standards (NGSS)*
- National Governors Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO)'s, *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and* Technical Subjects
- Partnership for 21st Century Skills, *A Framework for 21st Century Learning*

The following chart provides details on alignment among the core and component NGSS questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NGSS Framework and NGSS.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:

WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth's Place in the Universe

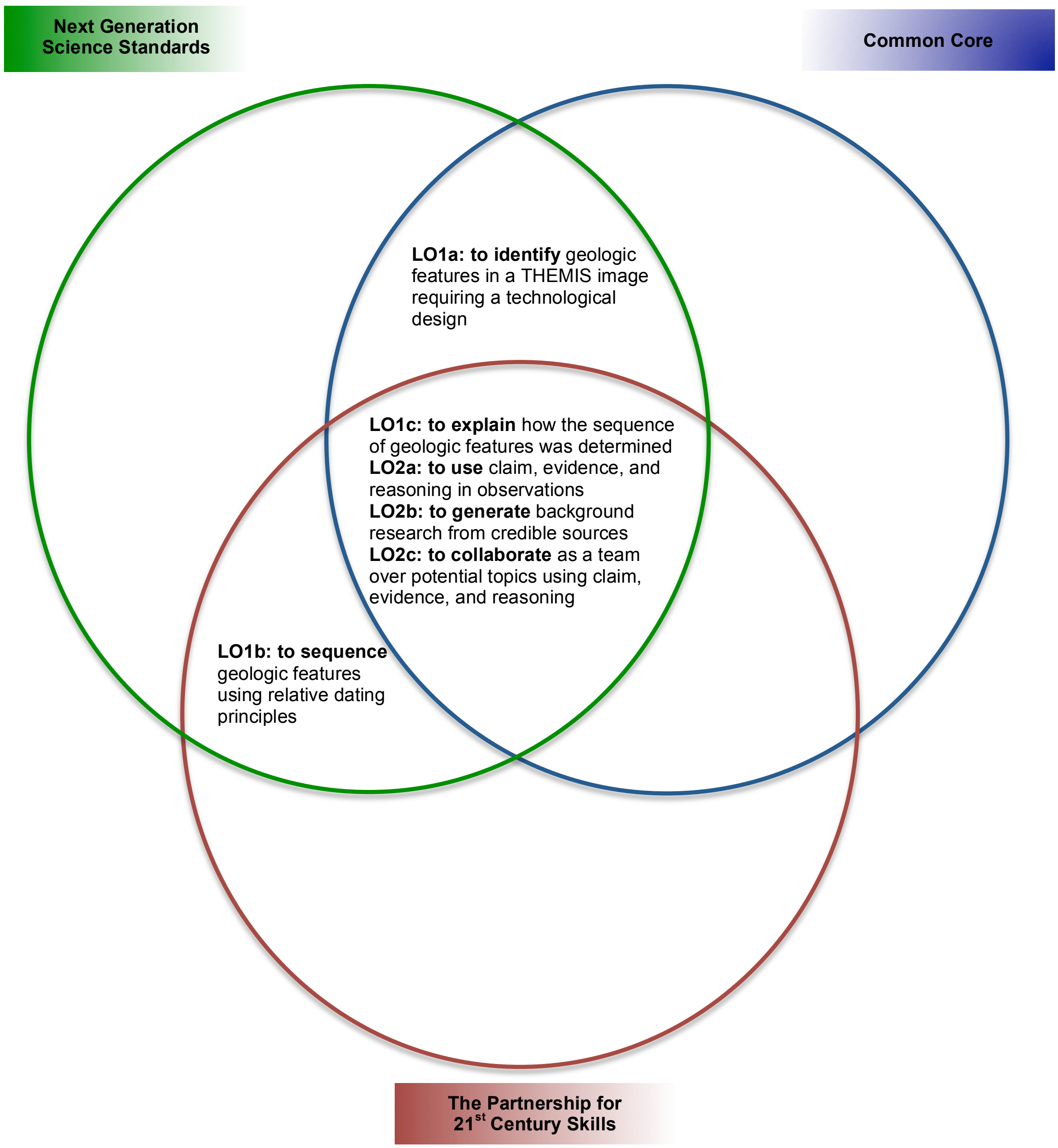
How do people reconstruct and date events in Earth's planetary history?

NRC ESS1.C: The History of the Planet Earth

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*
IO1: to reconstruct geologic events using empirical evidence	**LO1a. to identify geologic features in a THEMIS image** **LO1b. to sequence geologic features using relative dating principles** **LO1c. to explain how the sequence of geologic features were determined**	**NSES: UNIFYING CONCEPTS & PROCESSES: K-12: Evidence, models, and explanations** **NSES (D): EARTH AND SPACE SCIENCE: The Origin and Evolution of the Earth System Grades 9-12:** D3b, D3c **NGSS Disciplinary Core Idea:** **ESS1.C: The History of Planet Earth** (HS-ESS1-6) **ESS2.A: Earth Materials and Systems** (HS-ESS2-1; HS-ESS2-2) **NGSS Practices:** **Asking Questions and Defining Problems:** (Grades 9-12) **Using Mathematics and Computational Thinking** (Grades 9-12) **Constructing Explanations and Designing Solutions:** (Grades 9-12) **Obtaining, Evaluating, and Communicating Information** (Grades 9-12) **Engaging in Argument from Evidence** (Grades 9-12) **NGSS Cross-Cutting Concept:** **Patterns** (Grades 9-12) **Scale, Proportion and Quantity** (Grades 9-12) **Cause and Effect** (Grades 9-12) **Stability and Change** (Grades 9-12)
IO2: to use an argument to establish a research topic through collaborative debate and decision making	**LO2a. to use claim, evidence, and reasoning in observations** **LO1b. to generate background research from credible sources** **LO1c. to collaborate as a team over potential topics using claim, evidence, and reasoning**	

3.0 Learning Outcomes, NGSS, Common Core, & 21st Century Skills Connections

The connections diagram is used to organize the learning outcomes addressed in the lesson to establish where each will meet the Next Generation Science Standards, ELA and Math Common Core Standards, and the 21st Century Skills and visually determine where there are overlaps in these documents.



4.0 Evaluation/Assessment

Rubric*:* A rubric has been provided to assess student understanding of the simulation and to assess metacognition. A copy has been provided in the Student Guide for students to reference prior to the simulation. This rubric will allow them to understand the expectations set before them.

5.0 References

Achieve, Inc. (2013). *Next generation science standards*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York: Longman.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications.* Colorado Springs: BSCS.

Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom.* Washington, DC: The National Academies Press.

Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.

National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards*. Washington, DC: Authors.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

The Partnership for 21st Century Skills (2011). *A framework for 21st century learning.* Retrieved March 15, 2012 from http://www.p21.org

(L) Teacher Resource. Mars Image Analysis Rubric (1 of 3)

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Instructional Objective 1: to reconstruct geologic events using empirical evidence
Instructional Objective 2: to use an argument to establish a research topic through collaborative debate and decision making

Related Standard(s)

National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as “hypothesis,” “model,” “law,” “principle,” “theory,” and “paradigm” are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

National Science Education Standards (NSES)
(D) Earth and Space Science: The Origin and Evolution of the Earth System

Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed (Grades 9-12: D3b).

Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years (Grades 9-12: D3c).

National Science Education Standards (NSES)
(A) Science as Inquiry: Abilities Necessary to Do Scientific Inquiry

Identify questions and concepts that guide scientific investigation (Grades 9-12: A1a)
Formulate and revise scientific explanations and models using logic and evidence (Grades 9-12: A1d)

National Science Education Standards (NSES)
(D) Earth and Space Science: The Origin and Evolution of the Earth System

Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed (Grades 9-12: D3b).

Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years (Grades 9-12: D3c).

*This lesson supports the preparation of students toward achieving NGSS Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below:

(HS-ESS1-5. HS-ESS1-6, HS-ESS2-1, HS-ESS2-2)

Next Generation Science Standards (NGSS)
Practices: Asking Questions and Defining Problems
(Learning Outcomes Addressed: LO2a, LO2b, LO2c)

Ask questions

- that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- to determine relationships, including quantitative relationships, between independent and dependent variables.
- to clarify and refine a model, an explanation, or an engineering problem.

Next Generation Science Standards (NGSS)
Practices: Using Mathematics and Computational Thinking
(Learning Outcomes Addressed: LO1a)

- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

- Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Next Generation Science Standards (NGSS)
Practices: Constructing Explanations and Designing Solutions
(Learning Outcomes Addressed: LO1a, LO1c, LO2a, LO2b, LO2c)

- Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Next Generation Science Standards (NGSS)
Practices: Engaging in Argument from Evidence
(Learning Outcomes Addressed: LO1a, LO1c, LO2a, LO2b, LO2c)

- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.
- Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Next Generation Science Standards (NGSS)
Practices: Obtaining, Evaluating, and Communicating Information
(Learning Outcomes Addressed: LO1a, LO1c, LO2a, LO2b, LO2c)

- Critically read scientific literature adapted for classroom use to determine the

central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
- Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Patterns
(Learning Outcomes Addressed: LO1a, LO1c, LO2a, LO2b, LO2c)

- Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Cause and Effect
(Learning Outcomes Addressed: LO1a, LO1c, LO2a, LO2b, LO2c)

- Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Scale, Proportion, and Quantity
(Learning Outcomes Addressed: LO1a, LO1c, LO2a, LO2b, LO2c)

- Students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Stability and Change
(Learning Outcomes Addressed: LO1a, LO1c, LO2a, LO2b, LO2c)

- Students understand much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over very short or very long periods of time. They see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: ESS1.C: The History of Planet Earth
(Learning Outcomes Addressed: LO1a, LO1b, LO1c)

- Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old.

- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: ESS2.A: Earth Materials and Systems
(Learning Outcomes Addressed: LO1a, LO1b, LO1c)

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Common Core State Standards
Reading for Informational Text Standards 9-12: Key Ideas and Details
(Learning Outcomes Addressed: LO1c, LO2a, LO2b, LO2c)

- Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

- Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Common Core State Standards
Reading for Informational Text Standards 9-12: Craft and Structure
(Learning Outcomes Addressed: LO1a, LO2b)

- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.

Common Core State Standards
Reading for Informational Text Standards 9-12: Integration of Knowledge and Ideas
(Learning Outcomes Addressed: LO2a, LO2b, LO2c)

- Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (9-10)

- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (11-12)

Common Core State Standards
Writing Standards 9-12: Research to Build and Present Knowledge
(Learning Outcomes Addressed: LO2b)

- Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (9-10)

- Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (11-12)

- Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. (9-10)

- Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (11-12)

- Draw evidence from informational texts to support analysis, reflection, and research. (9-12)

21st Century Skills
Communication
(Learning Outcomes Addressed: LO2c)

- Students model the practices of research science by informing others about their work, developing effective explanations, constructing and defending reasoned arguments, and responding appropriately to critical comments about their explanations. (Grade 12 Benchmark)

21st Century Skills
Collaboration
(Learning Outcomes Addressed: LO1a, LO1c, LO2c)

- Students collaborate with peers and experts during scientific discourse and appropriately defend arguments using scientific reasoning, logic, and modeling. (Grade 12 Benchmark)

21st Century Skills
Information Literacy
(Learning Outcomes Addressed: LO2b)

- Students are able to determine the verifiability of evidence presented in print and electronic resources to evaluate scientific claims. (Grade 12 Benchmark)

(L) Teacher Resource. Mars Image Analysis Rubric (1 of 3)

Learning Outcomes Assessment:

	Expert	Proficient	Intermediate	Beginner
LO1a. to identify geologic features in a THEMIS image	Geologic feature identifications are logical and supported by evidence	Geologic features are logical and somewhat supported by evidence	Geologic features are reasonably logical and somewhat supported by evidence	Geologic features are illogical and/or not supported by evidence
LO1b: to sequence geologic features using relative dating principles	Geologic sequences are logical and supported by relative age dating principles	Geologic sequences are logical and somewhat supported by relative age dating principles	Geologic sequences are reasonably logical and somewhat supported relative age dating principles	Geologic sequences are illogical and/or not supported by relative age dating principles
LO1c: to explain how the sequence of geologic features were determined	Geologic sequences are logical and supported by evidence	Geologic sequences are logical and somewhat supported by evidence	Geologic sequences are reasonably logical and somewhat supported by evidence	Geologic sequences are illogical and/or not supported by evidence
LO2a: to use claim, evidence, and reasoning in observations	THEMIS observations include drawings and scientific claims of feature type and formation, supported by evidence provided by the site and lesson, includes a detailed explanation of how this is evidence for the type of formation.	THEMIS observations include drawings and scientific claims of feature type and formation, supported by evidence provided by the site or lesson, includes an explanation of how this is evidence for the type of formation.	THEMIS observations include a drawing and labeling of the feature. Uses evidence from the site or lesson for feature identification.	THEMIS observations include a drawing and labeling of the feature.
LO2b: to generate background research from credible sources	Evaluate all sources for credibility and use informational text to develop a detailed summary describing the feature, how it forms, and the relative similarities and differences between Earth/Mars.	Evaluate most sources for credibility and use informational text to develop a detailed summary describing the feature, how it forms, and the relative similarities and differences between Earth/Mars.	Some sources are credibility and uses informational text to develop a brief summary describing the feature, how it forms, and the relative similarities and differences between Earth/Mars.	May use credible text to develop a brief summary describing the feature, how it forms, and the relative similarities and differences between Earth/Mars.
LO2c: to collaborate as a team over potential topics using claim, evidence, and reasoning	Presents a potential topic of interest to the team including the compelling evidence and reasoning from background research. Effectively shares ideas during collaboration and listens to ideas before providing constructive feedback.	Presents a potential topic of interest to the team including the compelling evidence and reasoning from background research. May shares ideas during collaboration and listen to ideas, but may have difficulty with constructive feedback to ideas.	Shares a number of ideas with the group but may not connect to evidence and reasoning of background research. May or may not fully listen to ideas and/or provide constructive feedback.	Sharing of ideas is limited to a neighbor or written form only. Allows the group to make the decision.

(L) Teacher Resource. Mars Image Analysis Rubric (2 of 3)

Partnership for 21st Century Skills

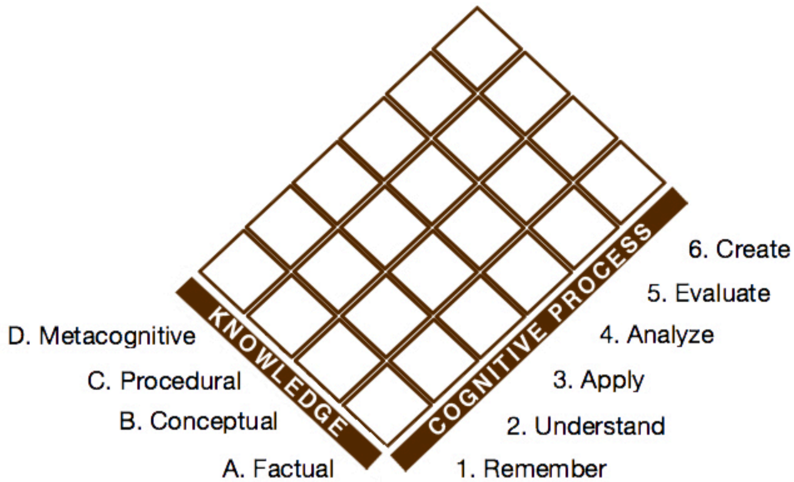
	Expert	Proficient	Intermediate	Beginner
Effectiveness of communication	Develops detailed explanations based on credible evidence. Compares explanations to those made by scientists and relates them to their own understandings of the geology.	Develops detailed explanations based on credible evidence. Relates them to their own understandings of the geology.	Develops explanations. Relates explanation to their own understandings of the geology.	Attempts to explain the geology based on own understanding of geology.
Effectiveness of collaboration with team members and class.	Extremely interested in collaborating in the group. Actively provides solutions to problems, listens to suggestions from others, attempts to refine them, monitors group progress, and attempts to ensure everyone has a contribution.	Extremely Interested in collaborating in the group. Actively provides suggestions and occasionally listens to suggestions from others. Refines suggestions from others.	Interested in collaborating in the group. Listens to suggestions from peers and attempts to use them. Occasionally provides suggestions in group discussion.	Interested in collaborating in the group.
Effectiveness of information literacy in background research	Locates reliable scientific information in reputable reference books, back issues of journals and magazines, on websites, and in computer databases.	Locates reliable scientific information in reputable reference books, back issues of journals *or* magazines, on websites.	Locates scientific information from a mixed variety of sources, some reputable, others less likely.	Locates information from websites indiscriminately.

(L) Teacher Resource. Mars Image Analysis Rubric (3 of 3)

Common Core – ELA

	Expert	Proficient	Intermediate	Beginner
Research to Build and Present Knowledge	Recalls relevant information from experience; summarizes information in finished work; draws evidence from informational texts to support analysis, reflection, and research.	Recalls relevant information from experience; draws evidence from informational texts to support analysis, reflection, and research.	Recalls information from experience; draws evidence from informational texts to support analysis, reflection, and research.	Recalls information from experience.
Key Ideas and Details	Uses specific evidence from text to support ideas. Develops an accurate and in depth summary, extending prior understanding and opinions.	Uses specific evidence from text to support ideas. Develops an in depth summary, extending prior understanding and opinions.	Uses information from text to support ideas. Develops a summary, extending prior understanding and opinions.	Supports ideas with details, relying on prior understanding and opinions.
Craft and Structure	Develops strong, accurate geologic vocabulary through feature identification and background research on those features.	Develops strong, geologic vocabulary through feature identification and background research on those features.	Develops vocabulary through feature identification.	Vocabulary is rudimentary toward geology and possibly based on prior understanding.
Integration of Knowledge	Successfully combines information from lesson with text found on web-based resources to develop a deep understanding of a geologic topic.	Successfully combines information from lesson with text found on web-based resources to develop an understanding of a geologic topic.	Combines information from lesson with text found on web-based resources to develop a summary of a geologic topic.	References text from web-based resources to develop a summary of a geologic topic.

(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)



This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are designed to support the target knowledge/cognitive process.

Knowledge	**Cognitive Process**
A. Factual **Aa:** Knowledge of Terminology **Ab:** Knowledge of Specific Details & Elements **B. Conceptual** **Ba:** Knowledge of classifications and categories **Bb:** Knowledge of principles and generalizations **Bc:** Knowledge of theories, models, and structures **C. Procedural** **Ca:** Knowledge of subject-specific skills and algorithms **Cb:** Knowledge of subject-specific techniques and methods **Cc:** Knowledge of criteria for determining when to use appropriate procedures **D. Metacognitive** **Da:** Strategic Knowledge **Db:** Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge **Dc:** Self-knowledge	**1. Remember** **1.1** Recognizing (Identifying) **1.2** Recalling (Retrieving) **2. Understand** **2.1** Interpreting (Clarifying, Paraphrasing, Representing, Translating) **2.2** Exemplifying (Illustrating, Instantiating) **2.3** Classifying (Categorizing, Subsuming) **2.4** Summarizing (Abstracting, Generalizing) **2.5** Inferring (Concluding, Extrapolating, Interpolating, Predicting) **2.6** Comparing (Contrasting, Mapping, Matching **2.7** Explaining (Constructing models) **3. Apply** **3.1** Executing (Carrying out) **3.2** Implementing (Using) **4. Analyze** **4.1** Differentiating (Discriminating, distinguishing, focusing, selecting) **4.2** Organizing (Finding coherence, integrating, outlining, parsing, structuring) **4.3** Attributing (Deconstructing) **5. Evaluate** **5.1** Checking (Coordinating, Detecting, Monitoring, Testing) **5.2** Critiquing (Judging) **6. Create** **6.1** Generating (Hypothesizing) **6.2** Planning (Designing) **6.3** Producing (Constructing)

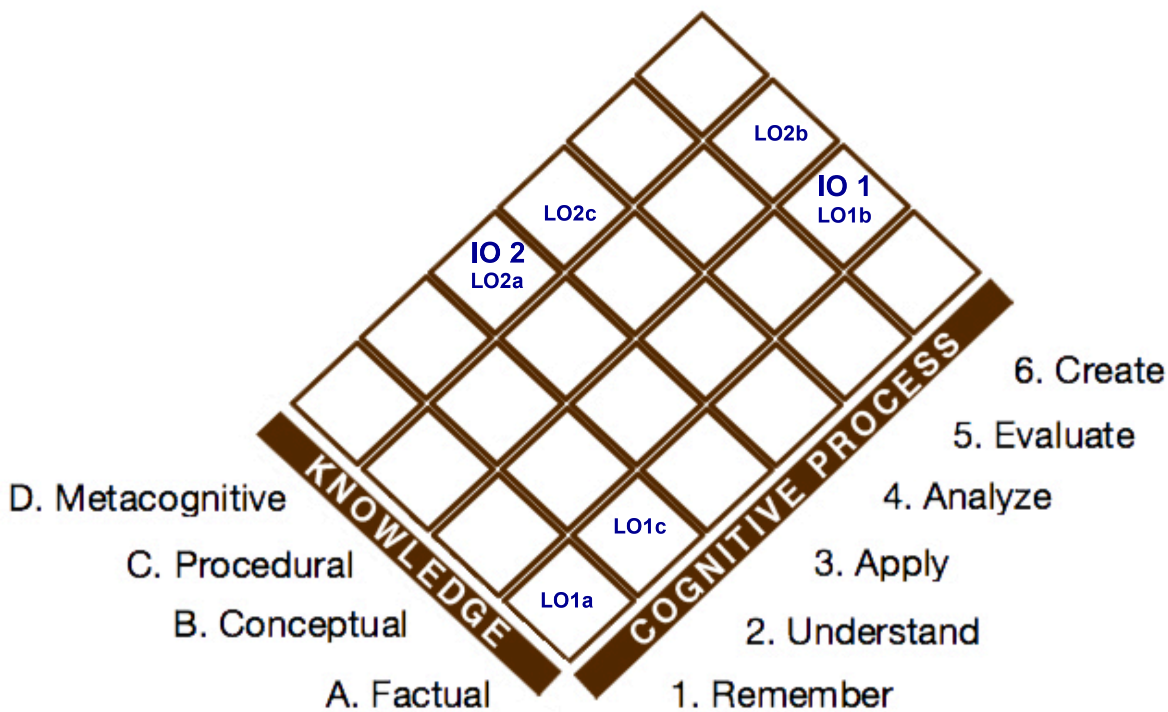
(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

IO 1: **to reconstruct** geologic events using empirical evidence (6.3; Bb)

LO1a. **to identify** geologic features in a THEMIS image (1.1; Ab)
LO1b. **to sequence** geologic features using relative dating principles (6.3; Bb)
LO1c. **to explain** how the sequence of geologic features were determined (2.7; Ab)

IO 2: **to use an argument** to establish a research topic through collaborative debate and decision-making (3.2; Da)

LO2a. **to use** claim, evidence, and reasoning in observations (3.2; Da)
LO2b. **to generate** background research from credible sources (6.1; Cb)
LO2c. **to collaborate** as a team over potential topics using claim, evidence, and reasoning (4.2; Db)



(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see 5.0 Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to (M, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (M, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

IO1: to reconstruct geologic events using empirical evidence
6.3: to construct
Bb: knowledge of principles and generalizations
IO2: to use an argument to establish a research topic through collaborative debate and decision-making
3.2: to use
Da: strategic knowledge

To meet that instructional objective, students will demonstrate the abilities:

LO1a: to identify geologic features in a THEMIS image
1.1: to identify
Ab: knowledge of specific details & elements
LO1b: to sequence geologic features using relative dating principles
6.3: to construct
Bb: knowledge of principles and generalizations
LO1c: to explain how the sequence of geologic features were determined
2.7: to explain
Ab: knowledge of specific details & elements
LO2a: to use claim, evidence, and reasoning in observations
3.2: to use
Da: strategic knowledge
LO2b. to generate background research from credible sources
6.1: to generate
Cb: knowledge of subject-specific techniques and methods
LO2c. to collaborate as a team over potential topics using claim, evidence, and reasoning
4.2: to find coherence
Db: knowledge about cognitive tasks, including appropriate contextual and conditional knowledge